JJEES

JJEES (2023) 14 (4): 280-286
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Remote Sensing and Aeromagnetic Study in Part of Sheet 244 Ado Ekiti Northeast for Groundwater Development, Nigeria

Hussain Olanrewaju Abubakar[1], Olusegun Omoniyi Ige[2], Saminu. Olatunji[3]

[1and3]Department of Geophysics, Faculty of Physical Sciences, University of Ilorin, PMB 1515 Ilorin
[2]Department of Geology and Mineral Sciences, University of Ilorin, PMB 1515 Ilorin

Received March 28, 2022; Accepted September 7, 2023

Abstract

The study area is located in the northern part of sheet 244 Ado Ekiti northeast of southwestern Nigeria to identify groundwater targets that could assist in improving the quality of life of rural communities. Airborne magnetic data, acquired from Nigerian Geological Survey Agency (NGSA), and the remote sensing data were interpreted to identify dykes, lineaments, and magnetic sources that could control groundwater occurrences. Data processing applied to the total magnetic intensity (TMI) includes residual magnetic intensity (RMI), reduction to the pole (RTP), first vertical derivative (FVD), vectorized first vertical derivative (VFVD), and analytical signal. Remote sensing data yielded five thematic maps, viz: geologic, land use, slope, elevation, and drainage density map. The length, and parallelism of magnetic lineaments in some parts of the area suggest emplacement under a tensional stress field along pre-existing zones of weakness. Lineaments extracted from the airborne magnetic data and satellite imagery data were superimposed on drainage lines to investigate the relative importance of structural features controlling the distribution of surface water and groundwater. In addition, the normalized difference vegetation index (NDVI), used in identifying areas of vegetation banding, enabled inferences of fracture zones and high moisture content in the soil. Integration of lineaments derived from aeromagnetic data and Landsat imagery together with the NDVI was able to identify the northern and central-eastern parts of the study area to be more prospective for groundwater occurrence, while the southern and south-western parts of the area are dry with no surface manifestation of groundwater.

Keywords: *Remote sensing, Aeromagnetic, Geology, Groundwater.*

1. Introduction

A typical use of Geophysics as a branch of geosciences is for hydrocarbon exploration typically at a depth greater than 1000 m. significant technological advances have been made in industries over the years, especially with seismic reflection techniques. In contrast, near-surface Geophysics for groundwater investigations is usually restricted to a depth less than 250 m below the surface and developments have not concentrated on one specific geophysical technique (Oluwatoyin and Ola-Buraimo 2022).

Water is a basic necessity of life which constitutes two-thirds of the whole body of human beings and coincidentally, that of the total earth mass. Underground water constitutes an important source of supplying drinking water. Virtually, every activity of man requires the use of water; whether domestically, industrially, in experiments in laboratories, or in any other forms of human daily activities. Wells drilled without proper geophysical and hydro-geological study often face failure challenges. In hard rock areas, groundwater is found in the cracks and fractures of the local rocks. Groundwater yield depends on the size of fractures and their interconnectivity. Groundwater generally occurs in rocks that are permeable enough to allow the accumulation and circulation along the geologic micro-structures. Generally, the information concerning the lithology, stratigraphic sequence, geologic structures, and hydro-geological characteristics of the subsurface materials can be provided through the application of the Electrical resistivity method (Koefoed, 1979). A large proportion (47%) of people in sub-Saharan Africa live without access to safe water sources in rural areas (Joint Monitoring Programme, 2008). The need for sustainable development and management of water resources, particularly groundwater resources, remains a major priority, especially within the context of climate variability, population growth, and pressures to increase food production (United Nations (UN), 2000).

2. Study Area

The area is located in the Northeastern part of Ekiti State, Southwestern Nigeria. It lies between geographic coordinates of Nothing 5^0 41' 40 "E and $5^0$43' 20" E and latitudes 7^0 31'50" N and 7° 62' 50" N (Figure 1). The topographic elevation in the area ranges from 345.0 to 375.0 m above mean sea level. The study covers an area extent of about 21000 km^2. The study area is located within the tropical rainforest of Southwestern Nigeria with dry and wet seasons. The wet season starts around mid-March and ends in October with an average annual rainfall of between 1500 mm and 2100 mm while the dry season starts around November and ends in March. Further, the average maximum temperature is about 33 °C (Ileoje, 1980).

* Corresponding author e-mail: abubakar.hussainolanrewaju3@gmail.com

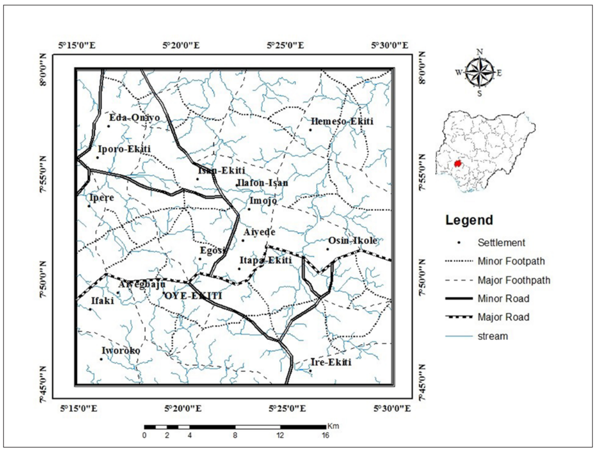

Figure 1. Location map of the study area.

3. Geology and Hydrogeology

The study area is underlain by rocks of the Precambrian basement complex of southwestern Nigeria (Rahman, 1976). It falls within three major lithostratigraphic units in which Gneiss and Granites are more pronounced. The Granitic rocks dominate the area (Figure 2). It is coarse-grained corresponding to the Precambrian age and is called Porphyritic Granite. The Granites occur as intrusive in low-lying outcrops within the Biotite Gneiss. Other rocks can be found in migmatite charnockite and other intrusive igneous rocks. In basement terrain, groundwater occurs in the weathered basement and the joints, fractures, or faults within the bedrock (Ademilua and Olorunfemi, 2000). The rock consists of Precambrian metasediments, Migmatites, Gneisses, Granites, and other intrusive igneous rock.

The Geomorphology of the study area, consisting of lowlands and extensively forested plain land, form high hills are prominent at Ire, Itapa, and Osin. Oye Ekiti has a low relief with the undulating surface formed as a result of differential weathering and erosion and the area is surrounded by hills which are moderate heights. Some of the hills are characterized by steep sides and deep valleys. It falls within the tropical rainforest zone of southwestern Nigeria. It has a tropical climate characterized by alternating dry and wet seasons. Rainfalls serve as the main source of groundwater replenishment (Akinola et al, 1986; Mohammed and Taufiq, 2022; Rzger Abdula et. al., 2021).

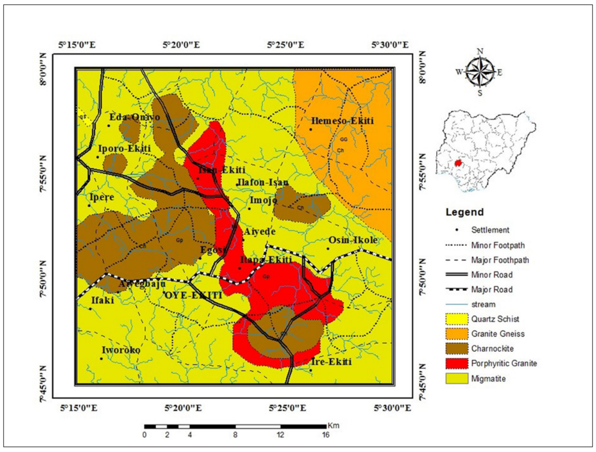

Figure 2. Geology map of the study area.

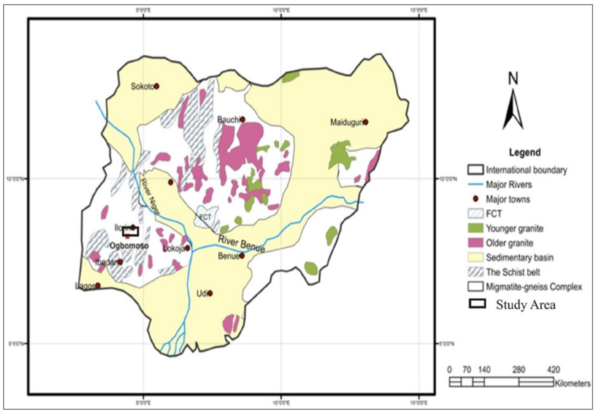

Figure 3. Geological Map of Nigeria showing the Study Area (Geological Survey of Nigeria, 2006).

4. Material and Methods

This study made use of both primary and secondary data. The primary data included Landsat 8 OLI and ASTER Digital Elevation Model. The secondary data included Lineament density maps and geological maps of the study area (Table 1). ArcGIS, Rockworks, ENVI, and PCI Geomatics Software were used for data processing.

Table 1. Data types and sources.

S/N	Data	Source	Scale
1	Landsat 8 OLI/TIRS	Glovis (http://glovis.usgs.gov)	30 m
2	ASTER DEM	Glovis (http://glovis.usgs.gov)	90m
3	Geological Map	Nigeria Geological Survey Agency	1:100,000
4	Soil Map	Center for World Food Studies (SOW-UV) (1997)	1:1,300,000
5	Topographical Map	Nigeria Geological Survey Agency (NGSA)	1:50,000

4.1 Method

The procedure adopted for this research comprised desk studies, fieldwork, and validation of findings. The steps involved are also presented in Figure 3. Desk studies involved the studying of literature and previous works on groundwater across Ekiti, Nigeria, and the world in general. Fieldwork involved geological mapping as well as a geophysical survey. While validation involves comparing the results of the outcomes of the GIS analysis with the geophysical survey.

To develop thematic maps of groundwater potential of the study area, lineament and land use/land cover maps were derived from the Landsat 8 OLI/TRS image using ENVI, PCI Geomatica, Rockworks, and ArcGIS software (Figure 3). Maximum likelihood classification (MLC) was used to produce the land use/land cover map of the study area. Elevation, slope, and drainage maps were produced with the spatial analyst tool and the Archydro tool of ArcGIS respectively. To derive the thematic maps from the secondary data, hard copy maps (geology and soil) were scanned and imported into the ArcGIS software then georeferenced to the World Geodetic System (WGS 84) coordinate system.

The weighting of the thematic maps was carried out using the Analytical Hierarchical Process (AHP). The AHP calculates weights based on the consideration of each theme's influence on groundwater accumulation by the technique of pair-wise comparison to compare the influence of one criterion with another on a scale of 1 to 9. Thus, 1 denotes equal importance between a pair of criteria, 3 means moderately more important, 5 is strongly more important, 7 is very strongly more important, and 9 implies extremely more importance of one criterion to the other. Meanwhile, 2, 4, 6, and 8 were used as intermediate values (Nigerian College of Aviation, 1999). The scale for comparison was determined based on previous studies (Sarup et al., 2011).

Mapping of the groundwater potentials of the study area was done by the weighted index overlay method in the ArcGIS. Before the overlay operations, the next step after weighing the maps was to carry out reclassification. This was done by assigning the new weight values to the maps' sub-units (sub-criteria) computed from the AHP. The reclassify tool in the spatial analyst tool of ArcGIS was used for this task. The groundwater potential zones map of the study area was produced by overlaying all thematic layers using the weighted index overlay.

Groundwater Potential Zone Map (GWPZ) = $\sum_{i,j=1}^{8} WiXj$

Where; Wi = % weight for each thematic map, Xj= reclassified map

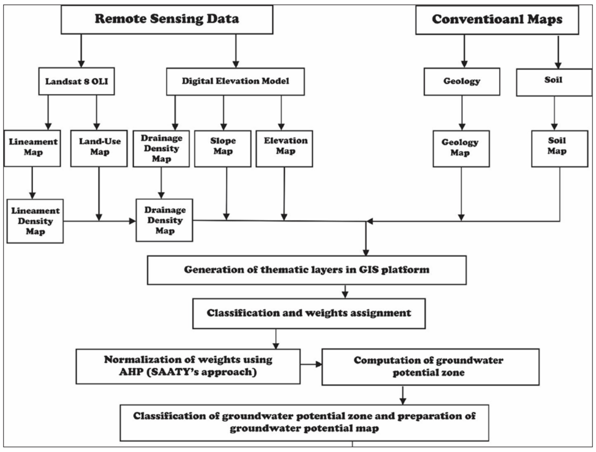

Figure 4. Flowchart for delineating groundwater potential in Oye-Ekiti and environs.

5. Result

5.1 Remote Sensing

5.1.1 Surface Lineament Analysis from DEM Image

Results obtained from DEM interpretation are discussed in other to demonstrate the effectiveness of remote sensing in lineament analysis for groundwater exploration study which is mostly to delineate zones that have groundwater potentials in the area of study. Figure 5 shows the digital elevation map of the study area, it can be seen that the area is characterized by high and low terrains. The mid-western part of the area has the highest elevation, this area consists of both charnockite and granite outcrops, occurring in the form of hills, boulders, ridges, and whaleback structures. This is responsible for the high elevation in the area. The low-elevation terrains on the other hand are characterized by migmatite and are mostly seen at the upper central and eastern part of the area.

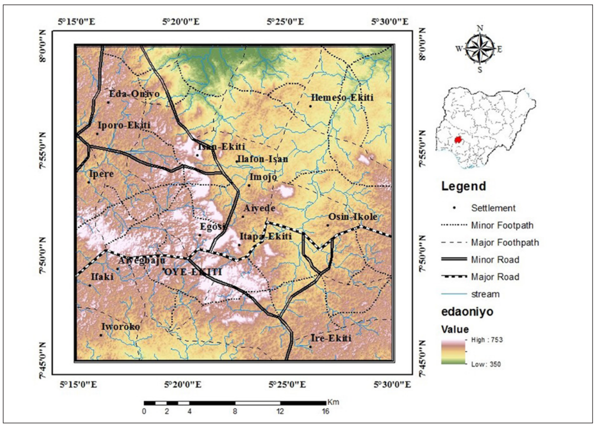

Figure 5. Digital Elevation Map of the study area.

Figure 6 shows the surface lineaments extracted from the DEM and imposed on the geologic map of the study area. It can be seen that lineaments are well distributed within the migmatites and granite gneiss in the study area, apart from the mid-western part of the area that is underlain by charnockite and granite, every other part has lineaments. The high concentrations of lineaments within the migmatite can be attributed to the polycyclic deformation that these rock types have gone through, creating a series of joints, faults, and fractures that can serve as openings for groundwater accumulation. This can also explain why the younger rocks have fewer lineaments within them, most especially in the mid-western part of the area.

Figure 7 shows the general orientation of the lineaments extracted from the Digital Elevation Model of the area of study which can be said to be closely related to tectonic activities such as fractures, faults, joints, etc. There is a huge concentration of lineaments in the NW-SE and the NE-SW directions, these fractures are favorable for groundwater locations (Olasehinde, 1999; Olasehinde et al., 1990; Obeidat and Awawdeh, 2021), other minor orientations include E-W, NNE-SSW, NNW-SSE, NEN-SWS, and ENW-WSW.

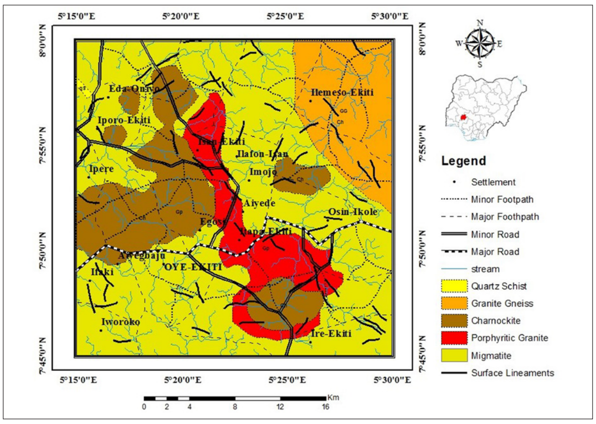

Figure 6. Extracted lineaments from DEM imposed on Geological Map of the area.

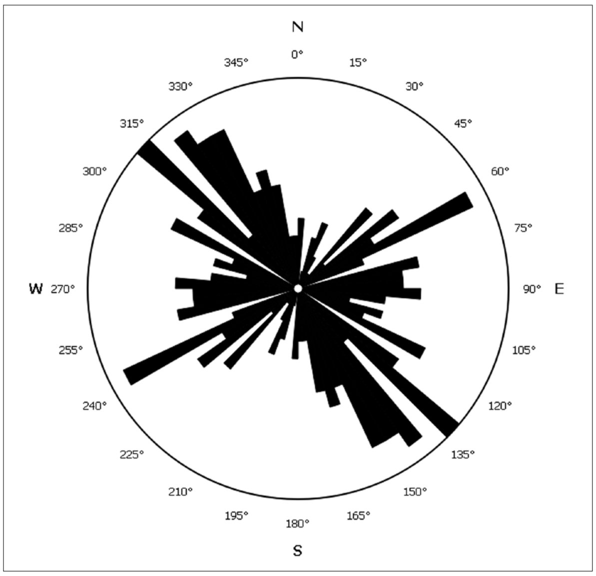

Figure 7. General orientation of Lineaments from DEM.

5.2 Aeromagnetic data Interpretation

An airborne magnetic survey is a supportive geophysical method for mapping subsurface bedrock geology (lithology) and structures due to variations in the magnetic susceptibility of rocks (Olasehinde and Raji, 2007). According to (Olasehinde and Ige, 2011), where the bedrock geology cannot be mapped due to thick jungle, swamp, deep weathering, or sand cover, aeromagnetic data can give information on the hidden geology using methods of inference that are similar to those used in photo geological interpretation (such as enhancement filters). One of the main goals for the use of magnetic data is to delineate geological structures and to some extent delineate lithology (Olasehinde and Ige, 2011) by gridding and applying enhancement tools.

Rocks of the study area showed different aeromagnetic responses that can be related to their lithology and tectonic activities that have resulted in the geological structures (e.g. folds, faults, and fractures) in the area. Linear features (geological structures) associated with the volcanic rocks are observed as moderately low and low magnetic signatures. The pink colors or characters in the presented figures are areas of high magnetic signature, whereas the blue characters represent areas of low magnetic signature.

5.2 Aeromagnetic data Interpretation

An airborne magnetic survey is a supportive geophysical method for mapping subsurface bedrock geology (lithology) and structures due to variations in the magnetic susceptibility of rocks (Olasehinde and Raji, 2007). According to (Olasehinde and Ige, 2011), where the bedrock geology cannot be mapped due to thick jungle, swamp, deep weathering, or sand cover, aeromagnetic data can give information on the hidden geology using methods of inference that are similar to those used in photo geological interpretation (such as enhancement filters). One of the main goals for the use of magnetic data is to delineate geological structures and to some extent delineate lithology (Olasehinde and Ige, 2011) by gridding and applying enhancement tools.

Rocks of the study area showed different aeromagnetic responses that can be related to their lithology and tectonic activities that have resulted in the geological structures (e.g. folds, faults, and fractures) in the area. Linear features (geological structures) associated with the volcanic rocks are observed as moderately low and low magnetic signatures. The pink colors or characters in the presented figures are areas of high magnetic signature, whereas the blue characters represent areas of low magnetic signature.

5.3 Subsurface Lineaments from First Vertical Derivative (1VD)

To observe the near-surface source magnetic features that are associated with geological structures, the first vertical derivative filter upwardly continued to 100 m was applied to the RTP grid. The 1VD filter helped decrease broad and more regional anomalies and rather enhanced local magnetic responses which are interpreted as structures in the area. Most of the structures delineated in the area coincided with already delineated structures in the Digital Elevation Model (DEM) map of the area. Prominent among these delineated structures is the northeast-southwest trending lineament at the eastern part of the map.

Figure 8 is a 1VD image of the study area upwardly continued to 100 m displaying near-surface source magnetic features that are associated with geological structures while Figure 9 is a vectorized map of the structures identified in Figure 8 imposed on the geological map of the area, while Figure 10 shows the orientation of the subsurface lineaments. The 1VD and Upward Continuation operators have helped attenuate broad, more regional anomalies and enhanced local, more delicate magnetic responses because of their sensitivity to shallow magnetic source bodies and contacts.

Assessment of the 1VD image of the area upwardly continued to 100 m (Figure 8) depicts a clear enhancement of observed structural features such as faults, folds, joints, and fractures. The general trends of the structures are in the NE-SW direction, while some others exist in the E-W and N-S directions, typical of the basement complex of Nigeria, it also corresponds with the observed structural trend observed on the field and on the DEM map. Unlike in the DEM map, there are more lineaments in the NE-SW directions. The majority of these structures may have been developed due to the various episodes of deformation that the migmatites have gone through, while others may be due to the stress developed during the emplacement of the granitoids. These structures may play openings for groundwater concentrations. These zones should be the sites of focus for groundwater exploration.

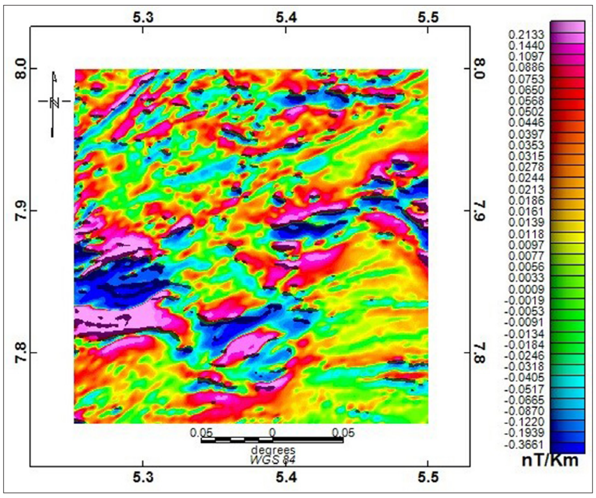

Figure 8. First Vertical Derivative (1VD) image of the study area.

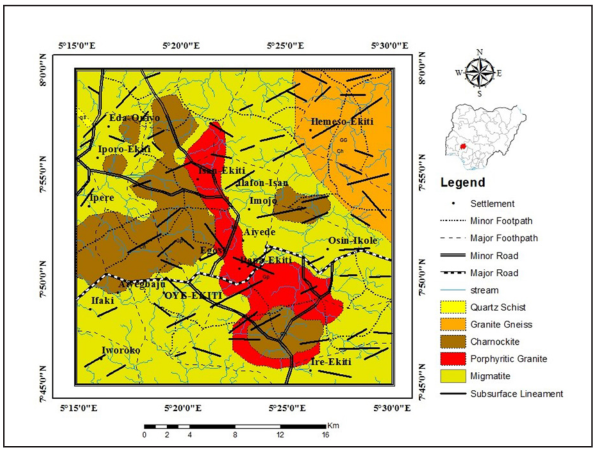

Figure 9. Lineaments from 1VD imposed on the geological map of the area.

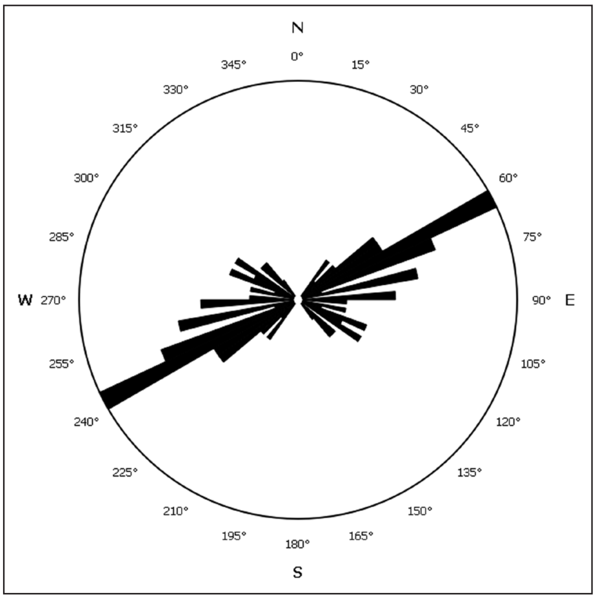

Figure 10. General orientation of Lineaments from 1VD.

Lineaments from both the DEM and IVD maps were combined and imposed on the geological map of the study area (Figure 11), to be able to separate areas of high groundwater potentials from low groundwater potentials. The lineaments were further used to produce the lineament density map of the study area (Figure 12) and subsequently the orientation of the combined surface and subsurface lineaments of the area (Figure 13). Figure 11 shows that the lineaments cut across every part of the area of study in various trends while figure 12 shows the areas of high lineament intersections of both the surface and subsurface lineaments. Areas like Eda-Oniyo, Ilemoso-Ekiti, Itapa-Ekiti, Isan Ekiti, Iworojo, Ire- Ekiti are located in an area having higher lineament intersections than the others, they can be classified as having higher groundwater potentials than the rest of the areas. Places like Aiyede, ipere, and Ifaki may not be well suited for groundwater exploration, the rest have medium groundwater potentials. Figure 13 shows the general orientation of the lineaments, it is obvious that the NE-SW orientation is the dominant trend in the area, which is a very good lineament direction for groundwater accumulation.

5.4 Combined surface and subsurface lineaments

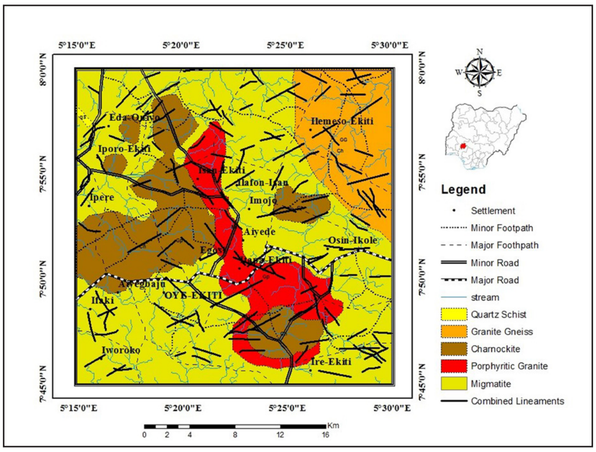

Figure 11. Lineaments from DEM and 1VD imposed on the geological map of the area.

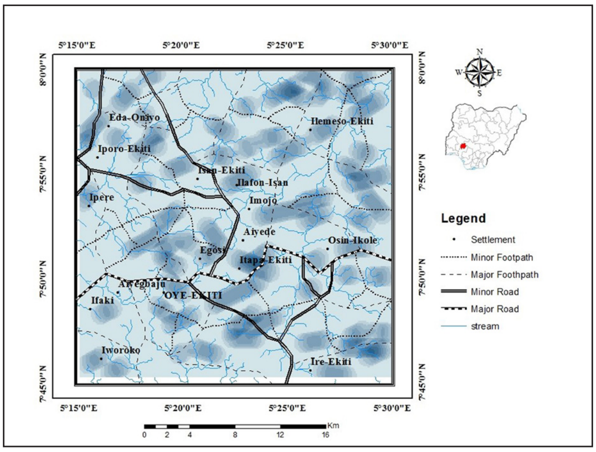

Figure 12. Lineaments density of the combined surface and subsurface lineaments map of the area.

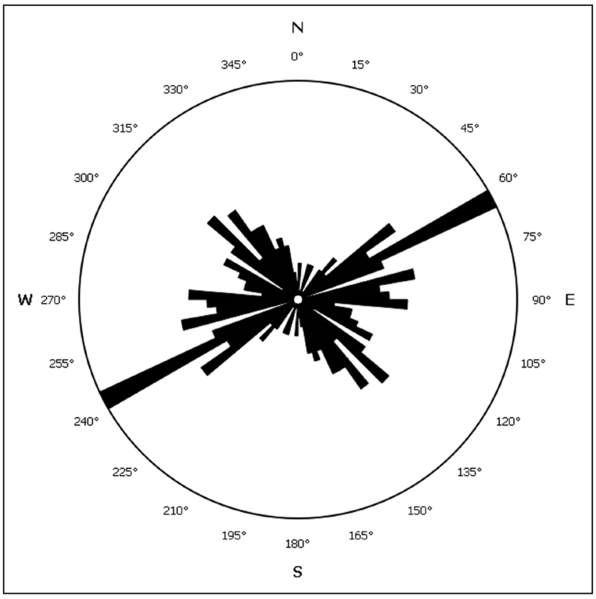

Figure 13. Orientation of the combined surface and subsurface lineaments map of the area.

5.5 Groundwater Potential Map

The various weights assigned to the thematic maps were used to produce the groundwater potential zones in the area of study. The groundwater potential of the study area is shown in Figure 14. The groundwater potential of the study area has been classified into five, namely: Very low, low, moderate, high, and very high. Very low groundwater potential area covers 1.4 km^2 (0.59 %) of the total area, low covers 72.18 km^2 (9.59 %), moderate covers 372.3 km^2 (49.44 %), high groundwater potential covers 272.12 km^2 (36.14 %), and very high groundwater potential covers 35 km^2 (4.64 %), as presented in Table 3.

From Figure 14, the western part of the area of study is dominated by very low to low groundwater potential while the southern part of the area of study is dominated by high and very high groundwater potential. Generally, low and moderate groundwater potential occupies the highest landmass in the area of study, this is to show that the basement complex terrain of Nigeria has a very low aquifer capability.

Places like Isan-Ekiti, Osin-Ikole, Imojo, and Ilafon-Isan all lie within the very low and low groundwater potential areas while Oye-Ekiti, Egosi, Itapa Ekiti, Eda Oniyo, Omu-Ekiti, Itagi, Iporo-Ekiti, etc. lie within moderate and high groundwater potential zone. Places like Ikole, Ire-Ekiti, Arigidi Omu-Ijalu, and Omu-Titun lie within the very high groundwater potential zone.

A closer look at figure 14 shows that areas of higher slope and high elevation values have low groundwater potential while places of high lineament density and low drainage density have high to very high groundwater potential. Also, geology played an important part in the groundwater potential of the study area as well and high and very high groundwater potential could be seen within the metamorphic rocks and very low to moderate within the igneous rocks. For land use, high and very high groundwater potential cuts across the farmland and forest more than the built-up, rivers, and rocky areas because forest and farmland enhance surface water infiltration into the subsurface.

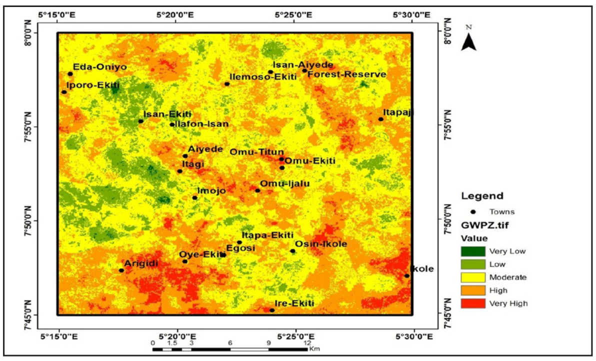

Figure 14. Groundwater Potential Map of the Study area.

6. Conclusion

From the analysis done the above results, Lineament density presents four dominant lineament orientations, N-S, E-W, NW-SE, and NE-SW, and these orientations are typical of the structures and deformation pattern within the basement complex of Nigeria. A lineament density map is a measure of the quantitative length of linear feature per unit area which can indirectly reveal the groundwater potentials as the presence of lineaments usually denotes a permeable zone. Lineament density values ranged from 0 to 2.52 km^2, areas with high lineament density are best for groundwater accumulation while areas with low lineaments are less favorable for groundwater accumulation as such, higher weights were assigned to high lineament values and low weights to low lineament values.

From the elevation map of the study low elevation values cover a total of 9.63 % while high elevation covers 7 % of the area. Intermediate values make up the remaining 83.46 %. Higher values were assigned to low elevation while lower values were assigned to high elevation.

The groundwater potential of the study area has been classified into five, namely: Very low, low, moderate, high, and very high. Very low groundwater potential area covers 1.4 km^2 (0.59 %) of the total area, low covers 72.18 km^2 (9.59 %), moderate covers 372.3 km^2 (49.44 %), high groundwater potential covers 272.12 km^2 (36.14 %), and very high groundwater potential covers 35 km^2 (4.64 %), the western part of the area of study is dominated with very low to low groundwater potential while the southern part of the area of study is dominated by high and very high groundwater potential. Generally, low and moderate groundwater potential occupies the highest landmass in the area of study, this is to show that the basement complex terrain of Nigeria has a very low aquifer capability.

References

Ademilua OL, Olorunfemi MO, Integration of hydrogeophysical and remote sensing data in the assessment of groundwater potentials of the basement complex terrain of Ekiti state, (2000), Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 4(1): 77-83.

Akinola et al, General Review of the Geology of the Precambrian to Lower Palaeozoic Rocks of Northern Nigeria. (1986) Geology of Nigeria, Elizabethan Publishing Co, 19-47.

Ileoje The Occurrence and Exploration of Groundwater in Nigeria Basement Rocks, (1980), Journal of Mining and Geol. 36, 1:2 131-146.

Joint Monitoring Programme (JMP), Global Water Supply and Sanitation Report, Joint Monitoring Program, (2008), WHO/UNICEF, World Health Organization, Geneva.

Koefoed, O. Geosounding Principles and Resistivity Sounding Measurements, (1979), Elsevier Science Publishing Company, Amsterdam International Journal of Geosciences, 5:8, 7: 31,

Mohammed Ibrahim and Taufiq Suleiman, Geoelectrical Study of Groundwater Potential at Waziri Umaru Federal Polytechnic's Gesse Campus BirninKebbi, Kebbi State, (2022), Nigeria. Jordan Journal of Earth and Environmental Sciences JJEES 13 (2): 82-8

Nigeria Geological Survey Agency (NGSA) (2006), Map of Nigeria showing Geological component.

Obeidat Mutawakil and Awawdeh Muheeb, Assessment of groundwater quality in the area surrounding Al- Zaatari Camp, Jordan, using cluster analysis and water quality index (WQI) (2021), Jordan Journal of Earth and Environmental Sciences, JEES 12 (3): 187-197

Olasehinde PI, An integrated geological and geophysical exploration for in the basement complex of west central Nigeria, (1999), Water Resour 10:46–49

Olasehinde P.I., Pal P.C. and Annor A. E., Aeromagnetic Anomalies and Structural Lineament in the Nigerian Basement Complex, (1990), Journal of African Earth Sciences, 11(5), 351-355.

Olasehinde, P.I. and Raji, W.O., Geophysical studies of fractures of basement rocks at the University of Ilorin, Southwestern Nigeria: Application to groundwater exploration. (2007), Water Resources. https://www.researchgate.net/publication/308606723

Olasehinde, P. I. and Ige, O.O, Preliminary Assessment of Water Quality in Ayede-Ekiti, South western Nigeria, (2011), Journal of Geology and Mining Research, 3(6). 147-152.

Ologe Oluwatoyin and Ola-Buraimo A. Olatunji, Evaluation of Aquifer Characteristics within Birnin Kebbi Metropolis, Northwestern Nigeria Using Geoelectric Survey, (2022), Jordan Journal of Earth and Environmental Sciences JJEES 13 (1): 60-63

Rahman MA, Review of the basement geology of southwestern Nigeria. In: Kogbe CA (ed) Geology,(1976), Journal of Mining and Geology, 27-35

Reeves, C., Reford, S., and Millingan, PAirborne geophysics: old methods, new images, (1997), In A. Gubbins (Ed.), Proceedings of the Fourth Decennial International Conference on Mineral Exploration, 13-30.

Rzger Abdula, Sardar Fatah, Gardun Salih, Mohammed Mustafa, and Muhammed Al, Source rock evaluation of the Chia Gara Formation in the Bekhme-1 well, Harir District, Kurdistan Region, Iraq, (2021), Jordan Journal of Earth and Environmental Sciences, JJEES 12 (2): 106-112

Saminu O et al, The use of vertical electrical sounding (VES) for groundwater exploration around Nigerian College of Aviation, (1999), Austria Journal of Earth Sciences. 21 (4): 223.

Sarup, J. Takal, K. M., Mittal, S. K., Estimation of soil erosion and net sediment trapped of upper-helmand catchment in Kajaki reservoir using USLE model and remote sensing e GIS technique, (2011). International Journal of Advanced Engineering Research and Science, 4(2), 237056

United Nations (UN), United Nations Millennium Declaration, United Nations General Assembly, (2000), A/RES/55/2, United Nations, New York.